SEMI-ANNUAL PROGRESS REPORT
(June 15, 1965, to December 15, 1965)

NASA MULTI-DISCIPLINARY RESEARCH GRANT

NsG-581

WASHINGTON UNIVERSITY

ST. LOUIS, MISSOURI

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SUBMITTED BY

G. E. Pake

G. E. Pake
Provost

Progress Report: Acoustic Spectrum of Solids

Principal Investigators: D. Bolef and J. Burgess

NASA Grant NsG-581/26-08-006

A. Microwave phonon techniques - Evaporation of Thin Films and Transducers.

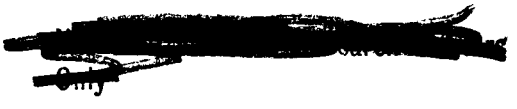
(1) Use of large evaporator for thin metal films.

A film thickness monitor purchased in June with funds from this grant has been installed and has increased the utility of the vacuum deposition system. A large number of films of indium, tin, aluminum, lead and vanadium have been prepared with special emphasis on control of grain size and parallelism of the surfaces. Effects of deposition rate, film thickness, substrate composition, substrate temperature and substrate cleanliness were studied.

(2) In order to avoid contamination of the commercial high-vacuum evaporator with fulfur and also in order to meet the special requirements for evaporation of CdS (or ZnS) piezoelectric transducers, a small, versatile vacuum evaporator was designed and built during this past year. A. Roestel, a student-technician, was primarily responsible for this apparatus. The unit is now being leak-checked, and preliminary runs will be made within the next few weeks. We will utilize this evaporator as a research instrument in developing methods for evaporating single crystal or oriented polycrystalline thin films which can act as generators of coherent phonon beams at microwave frequencies. Magnetrostrictive as well as piezoelectric thin film transducers will be studied. Careful control of film thickness may be obtained by means of a commercial thin film thickness monitor, which has been incorporated into the evaporator. Temperature control of the substrate to within $\pm 1^{\circ}C$ is available.

B. Acoustic Mössbauer Experiment.

The acoustic Mössbauer spectrometer described in the previous reports was completed with the construction of the water-cooled acoustic Mössbauer source assembly. The Mössbauer spectrometer was tested first by "running" the normal spectra of Fe^{57} in ion foils and in stainless steel foils, and was found to perform satisfactorily. Some time was then spent in learning how to attach the piezoelectric quartz transducer to the radioactive source and checking the acoustic properties (at 30mc) of the resulting compound resonator. After several unsuccessful attempts, a successful acoustic Mössbauer spectrum was obtained in October. Since then a number of runs have been made as a function of input acoustic power, with the expected changes in number and intensity of the "acoustic" side-bands.



Progress Report: Noise Reduction in Lasers and Masers

Principal Investigator: E. T. Jaynes

NASA Grant NsG-581/26-08-006

The aim of this project is to study random fluctuation effects in Laser oscillators and amplifiers, and other radiation detectors; and in particular to explore some theoretical possibilities for noise reduction. Effort is about equally divided between theoretical and experimental.

Theoretical. (C. Stroud, E. Jaynes) Application of quantum electrodynamics to idealized models of lasers is being studied, with the aim of (a) determining long-term coherence properties in the interaction of atoms and radiation, which conventional perturbation theory fails to give; and (b) obtaining more detailed comparisons of quantum electrodynamics and semiclassical radiation theory with regard to fluctuation and coherence effects. The Hamiltonian matrix has certain "dynamical symmetry" properties, not related to any spatial symmetry, which lead to simplifications of what had been thought to be very difficult problems. It is planned to continue this work, extending it to more realistic models.

Also underway is development of a new statistical theory of photoelectric counting experiments, which is needed in order to carry out optimum data reduction, or design optimum experiments to measure properties of random light. This work will be reported at the Conference of an Optical Coherence Theory to be held at Rochester in June 1966.

Experimental. (J. Rothschild, C. Tyler, E. Jaynes) Humidity and vibration conditions made it impossible to carry out experiments during the summer in our old quarters, so effort was concentrated on construction of needed apparatus. Accumulation of optical equipment has now reached the point where the "second round" of experiments is starting in the new Compton Laboratory. A long-path Michelson interferometer is being set up, and a method for eliminating effects of vibration and air turbulence by differential photocell observation of the fringes has been devised, with which we hope to measure laser light fluctuations in amplitude and phase. Two methods of phase-modulating the light, by Faraday rotation and by varying the refractive index of a crystal, are being studied.

A recent grant from ARPA will enable us to obtain a great deal more needed equipment, with which more detailed measurements, involving counting individual photoelectrons, can be carried out; and facilities for building our own laser oscillators and amplifiers will be obtained. This should greatly accelerate the experimental program, which in the immediate future will concentrate on long-path interferometer measurements and photoelectric counting experiments, to which will be added measurements on laser amplifiers as soon as the needed facilities are available.

Progress Report: Cryogenic Detectors

Principal Investigator: K. Luszczynski and R. E. Norberg)

NASA Grant NsG-581/26-08-006

It remains the objective of this program to continue the development of very fast and sensitive heat detectors, low noise cryogenic amplifiers, and effective data processors for noisy signals from cryogenic devices.

The vacuum deposition system purchased with the aid of this grant has been used extensively in the preparation of carbon and metal film devices used in several cryogenic experiments.

In connection with the vacuum deposition of films, various methods of cleaning of substrates have been investigated. The most satisfactory films were obtained on substrates which were bombarded with a beam of positive ions in the vacuum chamber. The method of cleaning and preparation of satisfactory substrates requires further investigation.

The carbon films have been used in experiments on the detection of heat pulses in liquid helium. Suitable films, i.e. films having the desired temperature sensitivity in the region of interest can be produced by the simultaneous deposition of carbon and metal in proportions which are determined empirically.

The thin film cryogenic liquid-level indicator recently developed under this project has continued to prove a reliable and sensitive device. It is now in standard use on several of our experimental dewar vessels.

Progress Report: Anomalous Spin Interactions

Principal Investigator: Peter R. Phillips

NASA Grant NsG-581-26-08-006

This experiment is designed to look for anomalous torques exerted on electron spins, in addition to the usual $\mathbf{M}\cdot\boldsymbol{\sigma}$ terms due to magnetic fields. Soon after submitting our status report a year ago, we decided to concentrate all our efforts on one type of experiment, involving a delicate torsion fiber carrying a bar magnet. We preferred this technique to others, using fluxgate magnetometers or nuclear resonance, because the main techniques had already been developed to ample precision by workers at the Kettering Laboratory, Oakland University. We did try a precession experiment with deuterons at the National Bureau of Standards, but concluded that a usable signal could be obtained only with specially designed equipment, which is the subject of our proposal for the coming year.

Last summer we obtained support from the National Science Foundation, and the combined funds have enabled us to make excellent progress. The pendulum is complete, and is mounted on a rugged aluminum cart, carrying a large pumpout line, with pumps at the end farthest from the pendulum. Our vacuum problems seem to be solved. The orientation of the pendulum is sensed by an optical lever which is modelled after that of Dicke. This is complete. Feedback and control circuits are being built and tested. A large set of orthogonal Helmholtz coils has been built, and will be used in testing the equipment during the spring. Next summer we anticipate taking everything up to Oakland University, unless we find that we can, after all, achieve sufficient stability and accuracy here in St. Louis.

An important development has been a deeper analysis of the field-theoretic basis of the ideas involved, and the discovery that such theories suggest an origin for photons and gravitons. We used ideas due to Nambu and Bjorken to estimate the gravitational constant, and related it to the observed decay rate of $K^{o} \rightarrow 2\pi$, which has not hitherto been thought to be connected with gravitation. The agreement is strikingly good. A paper has been written and submitted to the Physical Review.

Progress Report: Sub-millimeter Astronomy

Principal Investigator: M. W. Friedlander

NASA Grant NsG-581/26-08-006

This new program, presently funded partly from the Washington University/ NASA Grant and partly from our own National Science Foundation Grant, is slowly making progress. A Golay cell is being used for laboratory testing and for checking out a reflecting telescope system, based on a 60" searchlight mirror. A cryogenic detector is on order and negotiations are in progress to obtain, from the Jet Propulsion Laboratory, some high quality electro-formed nickel mirrors. These are light enough to be sent up on our projected high altitude balloon flights.

The present program is aimed at producing a balloon-borne payload which will have a 60" reflector and be oriented in desired directions. Ultimately, it is hoped to use interference spectroscopic methods to map out the entire spectrum in the wavelength region of interest, but, as a first step, transmission interference filters will be used. Thin films and electro-formed metal grids are being investigated for this purpose. A laboratory black-body standard source is being constructed.

With this high-altitude equipment, we wish to attempt two main experiments: (i) look for the 28 micron line expected from molecular hydrogen, and (ii)) scan the spectrum of such bright objects as some supernovae remnants and quasi-stellar radio sources.

For (i): molecular hydrogen has not yet been detected in astronomical objects nor in the galaxy, yet there are sound estimates which would suggest appreciable quantities. The 28 micron line results from the ortho-para hydrogen transition, and is unobservable from ground level on the earth, because of atmospheric absorption. For (ii): the extension of our knowledge regarding radio sources will greatly increase our understanding of the processes involved in particle acceleration and the general energy balance.

This program is being carried out jointly with the group under Professor Chang, in the Department of Electrical Engineering.

Progress Report: Investigation of Submillimeter Waves Via Gas Laser Techniques

Principal Investigator: W.S.C. Chang

NASA Grant NsG-581/26-08-006

The purpose of this project is to investigate the extension of gas laser techniques for submillimeter wave generators either as a source for nonlinear action or as a pulsed laser itself. The first phase of the program is simply to establish a pulsed gas laser facility in the Department of Electrical Engineering at Washington University.

During the past six months, a gas laser has been designed as shown in Fig. 1. The essential features of this gas laser are:

a. It uses a modulator from a C PS-6B radar as a power source that is capable of delivering 30 KV and 70 amps over 1 to 2 μ sec. period; this pulsed power source is adequate to excite most of the singly ionized transitions and some of the doubly ionized transitions.

b. The entire laser is mounted on an optical bench so that mode selectors, non-linear elements, Kerr cell shutters, etc. can be mounted easily inside and outside the cavity.

c. A precision gimble mount is used to hold the resonator so that the interchangeable resonator blanks, reflection coated at different wavelength could be changed without losing the rough alignment of the optical cavity.

d. Initially an external cavity hemispherical resonator was designed to use with the visible light and infra-red singly and doubly ionized lasers because its ease of alignment and its mode stability.

e. By changing the laser tube and cavity to an internal resonator system, this same system will be used for the 340 μ CN submillimeter laser. The laser resonator configuration is such that it should oscillate in one transverse mode when it is aligned properly.

Equipment, laser, vacuum systems, radar pulser, resonator, optical benches and accessories, detectors, interference filters, and many other pieces of equipment for this laser have already been ordered and partially constructed. During the next six month period, it is expected that singly ionized laser action should be observed in the near future. After the observation of the first laser action, our research plans will be branched into two directions:

Progress Report: Investigation of Submillimeter Waves Via Gas Laser Techniques (continued)

Principal Investigator: W.S.C. Chang

a. The construction of the 340μCN laser with a new resonator tube having internal cavity and

b. The investigation of mode structure and its influence to non-linear optical effects. The study in (b) will lead to the understanding of coherence in non-linear optical effects and then to the generation of submillimeter waves. This is necessary because it is believed that coherence is an important limiting factor in the generation of submillimeter waves via optical non-linear interactions.

To be specific we are already in the process of designing a CN laser and we are collecting the existing data and making theoretical calculations on the phase-matching of the non-linear optical interaction using two adjacent oscillating wavelengths of a singly ionized laser. Once these two initial calculations and design are finished, equipment and non-linear material will be ordered and constructed for that purpose.

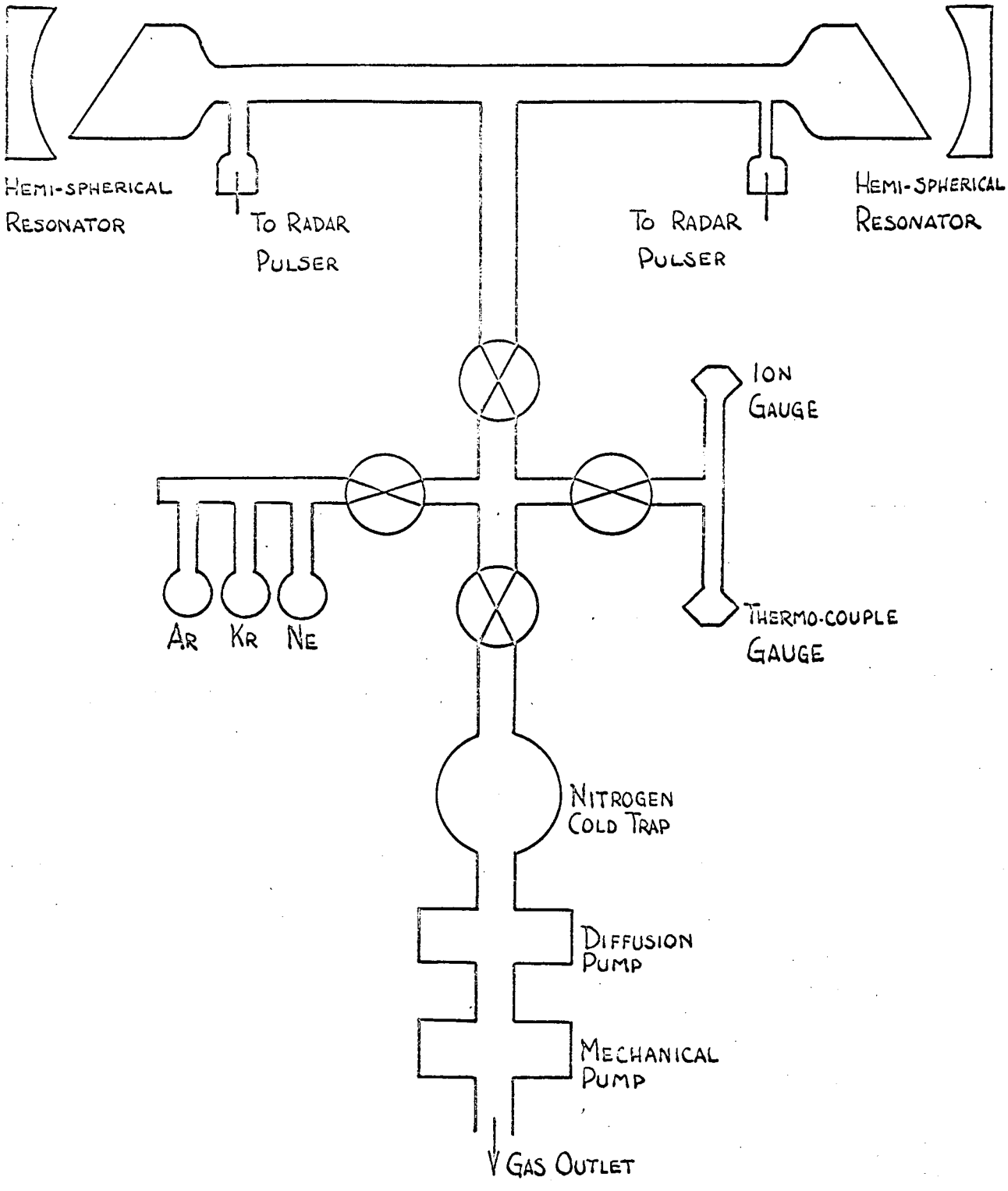


FIG. 1 SCHEMATIC DIAGRAM OF THE SUBMILLIMETER GAS LASER.

Progress Report: Semiconductor Detectors and Nuclear Spectroscopic Studies

Principal Investigator: D. Sarantites

NASA Grant NsG-581/26-08-006

Considerable progress has been made in the construction of nuclear radiation spectrometers using semiconductor detectors. Thus a vacuum chamber for mounting a Si(Li) 3-mm deep detector, operated at -40°C by thermoelectric cooling, has been constructed and is presently used in β -ray and conversion electron spectrometry. This spectrometer can be mounted on an angular correlation apparatus, designed and constructed so that directional correlations between coincident $\beta^- - \gamma$, $e^- - \gamma$ and $\gamma - \gamma$ rays can be accurately measured. The same apparatus was also designed for measurements of the plane polarization of coincident γ-rays. These measurements will allow the determination of the relative parities and the angular momenta of the states involved in the cascades.

Thick Ge(Li) detectors with intrinsic thickness up to 7 mm and 5 cm^2 active area have been fabricated. A second apparatus for mounting and operating the Ge(Li) detectors at liquid nitrogen temperatures is presently under construction.

A time pickoff unit (Ortec Model 260) and a time pickoff control unit (Ortec Model 403) have been purchased. Two such units will be used in conjunction with a time to pulse height converter for the determination of short (to nsec) life times of nuclear excited states by the delayed coincidence technique.

The gear and the driving motors needed in a 36 inch scattering chamber will be purchased. This equipment will be used in conjunction with the Washington University cyclotron group in nuclear spectroscopic studies via direct nuclear reactions.

Progress Report: Investigation of Complex Ions

Principal Investigator: L. Helmholz

NASA Grant NsG-581/26-08-006

$Cr(CN)_6^{\equiv\equiv}$ (A. Wolberg)

The E.P.R. studies of the octahedral complex of $Cr(CN)_6^{\equiv\equiv}$ in cubic $Cs_2LiCo(CN)_6$ crystal at room and liquid nitrogen temperatures has essentially reproduced previous experiments in lower host symmetries as $K_3Co(CN)_6$ which have required enriched ^{53}Cr samples and experiments in entirely different environment as Cr^{43} in Mgo. In addition our experiment shows indication of further splitting of the Cr lines presumably due to ^{13}C. To be positive about this interpretation of these splittings we plan to carry out additional experiments with lower temperatures (Liquid Me) and with samples with enriched ^{13}C.

$MnCl_4$ (?) (F.D. Tsay)

When a suspension of manganese dioxide in absolute ether is saturated with dry hydrogen chloride gas, a green solution is obtained, which turns violet on further dilution of ether. It is found that such a color change has to be associated with the complex halides (e.g. $MnCl_4$) formed in solution. Further E.S.R. studies are being carried out to confirm the existence and structure of these complex ions responsible for the color changes observed.

Progress Report: Reaction Studies of Hot Silicon Radicals

Principal Investigator: Peter P. Gaspar

NASA Grant NsG-581/26-08-006

The principal efforts to date have centered on the system $Si^{31} + CH_4$, the reaction mixtures consisting of phosphine and methane. Silane has been identified as the major product by comparison of its vapor-chromatographic retention times on several columns with those of authentic silane. When silane is included in the reaction mixture the major product appears to be disilane with silane also being produced. The identification of the major product as disilane is tentative. The effect of phosphine-methane ratio, moderator and scavengers on the product distribution is currently being studied.

A major contribution to the experimental technique of hot-atom chemistry has been the development of a dual-flow counter detection system for a vapor chromatograph. By passing a mixture of radioactive silicon compounds through a flow counter before fractionation as well as afterwards it is possible to measure total volatile activity and the component activities on the same sample without the necessity of handling aliquots.

Progress Report: The Synthesis of Unknown Strained Ring Systems

Principal Investigator: A. Hortmann

NASA Grant NsG-581/26-08-006

In attempting to prepare cyclopropene derivatives via reaction of acetylenic ketones with dimethyloxosulfonium methylide (I), it was found, in one case, that a thiabenzene-1-oxide was produced. Studies are being continued as outlined in the attached communication.

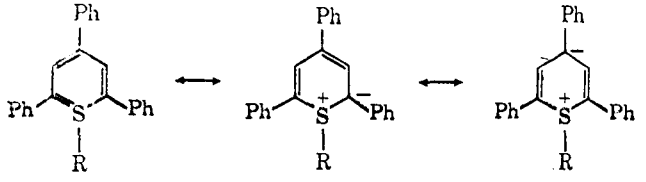
Studies of the reaction of I with azirenes and aziridines are also presently in progress.

[Reprinted from the Journal of the American Chemical Society, 87, 4972 (1965).]

Thiabenzenes. A Stable Thiabenzene 1-Oxide

Sir:

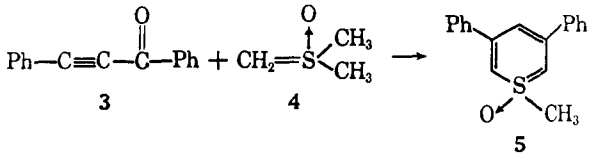
Several thiabenzene derivatives (**1a**, **2a**) have been reported recently[1]; of current interest is the question of



1a, R = CH_3
2a, R = Ph

1b **1c**

whether these structures are ylene-like and possess appreciable cyclic aromatic conjugation or whether they are more accurately represented as hybrid structures principally composed of ylide-like contributing structures such as **1b** and **1c**. In this communication the novel synthesis of a related heterocycle, 1-methyl-3,5-diphenylthiabenzene 1-oxide, is reported.



3 **4** **5**

In a typical preparation a solution of 3-phenylpropiolophenone (**3**, 8.0 g., 0.039 mole) in 20 ml. of dry dimethyl sulfoxide was added rapidly under nitrogen to a solution of dimethyloxosulfonium methylide (**4**,[2] 0.082 mole) in 80 ml. of dimethyl sulfoxide at 20°. After 20 hr. at room temperature the resulting red-orange solution was poured into water; the precipitated solid was crystallized from ethyl acetate–petroleum ether (b.p. 63–69°) to yield 6.75 g. (62%) of 1-methyl-3,5-diphenylthiabenzene 1-oxide (**5**) as yellow needles, m.p. 147–148.5°. A purified sample of **5** (sublimed at 140° (0.05 mm.)) melted at 148–148.5°; ultraviolet[3] λ_{max}^{MeOH} 240 mμ (ε 26,200), 364 mμ (ε 10,000); infrared $\nu_{max}^{CHCl_3}$ 1527, 1490, 1385, 1371, 1130, and 697 cm.$^{-1}$; n.m.r. ($CDCl_3$) signals at δ 7.15–7.65 (10 H, multiplet), 6.19 (1 H, triplet, J = 1.1 c.p.s.), 5.75 (2 H, doublet, J = 1.1 c.p.s.), and 3.50 (3 H, singlet). *Anal.* Calcd. for $C_{18}H_{16}SO$: C, 77.12; H, 5.75; S, 11.42; mol. wt., 280.4. Found: C, 77.15; H, 5.76; S, 11.60; mol. wt., 276 (osmometer), 323 (Rast).[4]

(1) G. Suld and C. C. Price, *J. Am. Chem. Soc.*, **83**, 1770 (1961); **84**, 2094 (1962); C. C. Price, M. Hori, T. Parasaran, and M. Polk, *ibid.*, **85**, 2278 (1963).

(2) E. J. Corey and M. Chaykovsky, *ibid.*, **87**, 1353 (1965); **84**, 867 (1962).

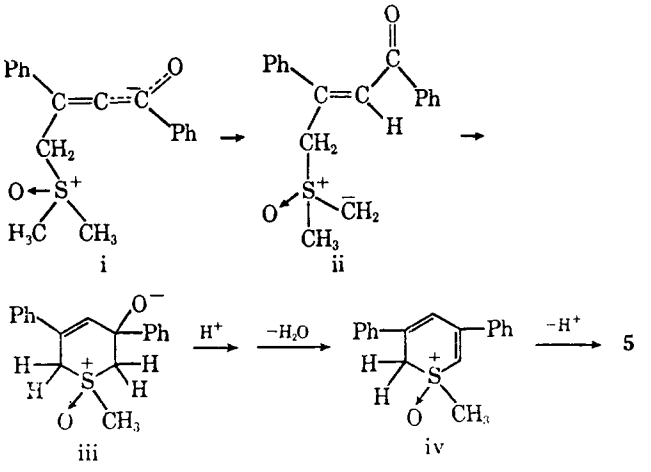
(3) The ultraviolet spectrum was unchanged when measured in dilute methanolic sodium hydroxide; addition of hydrochloric acid to a neutral solution of **5** effected appearance of a new band at 313 mμ. No pK values have been obtained as yet.

(4) A reasonable route for the formation of **5** might involve initial Michael addition of **4** to **3** to give i, proton exchange to yield ii, followed by the transformations ii → iii → iv → **5**.

Refluxing **5** with D_2O–CH_3OD–NaOD (21 hr.) followed by aqueous workup gave **5**-d_3 in which the methyl hydrogens were exchanged (absence of 3 H singlet at δ 3.50); a solution of **5** in deuterioacetic acid (containing a trace of D_2O) showed disappearance of the signals at δ 5.75 and 6.19 and appearance of a broad singlet (*ca.* 3 H) at δ 8.0 due to rapid exchange of the S-ring protons.[5]

The remarkable stability of **5** when compared with that of **1a** and **2a** is particularly noteworthy.[6] A similar relationship has been observed between dimethyloxosulfonium methylide and dimethylsulfonium methylide.[2] The behavior of **5** in acidic media taken with the n.m.r. peak positions (in $CDCl_3$) for the S-ring protons suggests ylide-like character for **5**. However, the possibility of some cyclic aromatic conjugation involving the use of 3d orbitals by sulfur[7] cannot be discounted on this basis alone; further work leading to clarification of the electronic structure of thiabenzene 1-oxides would be of considerable theoretical interest.

Studies on the synthetic utility of the reaction of acetylenic compounds with sulfur ylides as a general route to thiabenzene derivatives are being continued; the chemical reactivity and photochemistry of **5** are also being investigated.[8]



i ii iii iv **5**

(5) Facile protonation has been reported for the somewhat similar 1,1-diphenylphosphabenzene system: G. Märkl, *Angew. Chem.*, **75**, 669 (1963).

(6) Whereas **1a** and **2a** rearrange readily at 25° to yield thiapyrans, **5** can be evaporatively distilled at 160° (0.05 mm.) without decomposition; compound **5** is stable to air whereas **2a** reacts rapidly with oxygen to yield a "peroxide" (see ref. 1).

(7) See, however, R. Breslow and E. Mohacsi, *J. Am. Chem. Soc.*, **84**, 684 (1962), and references cited therein.

(8) This work was supported by a grant to Washington University from the National Aeronautics and Space Administration. Thanks are accorded to Mr. Daniel Schiffer for the n.m.r. spectra.

Alfred G. Hortmann
Department of Chemistry, Washington University
St. Louis, Missouri 63130
Received September 7, 1965

Progress Report: Methods of Transition State Characterization

Principal Investigator: Joseph L. Kurz

NASA Grant NsG-581/26-08-006

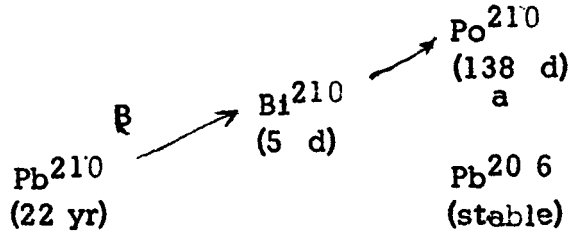
Work on the various approaches outlined in the previous progress report has been proceeding satisfactorily. The following results are particularly worthy of note. For the uncatalyzed hydrolysis of ethyl trichloroacetate, a preliminary value of $\delta H^{*}/\delta T$ is -55 cal. mole^{-1}, deg.$^{-1}$. A detailed interpretation quantity in terms of $\triangle C_p^{*}$'s for specified steps in the reaction must await the results of oxygen-18 tracer studies which are soon to be initiated. The calorimetric portion of the measurements required for the determination of $\triangle Cp^{\circ}$ for carbonyl hydration have been completed, and the equilibrium constant measurements necessary for their interpretation are being started. As a "free" bonus, these measurements also yield rate data which will permit application of the pK_a^{*} method to characterization of the hydration transition state.

Progress Report: Thorium and Uranium Contents of Ultramific Rocks

Principal Investigator: H. A. Potratz

NASA Grant NsG-581/26-08-006

Work during the summer of 1965 on this project led to a procedure for determining the Pb^{210} content of marine carbonates. Pb^{210} is determined indirectly by measuring the Po^{210} activity associated with the sample.



A weightless deposit of Po^{210} is obtained by displacement on silver -- a mixture of cyclotron produced Po^{208} (half life 2.9 yr) and Po^{209} (half life 103 yr) being added to serve as a yield monitor. Alpha spectrophotometric analysis of the Po activity on the silver plate serves to determine the amounts of the three Po isotopes. We are now investigating the chemical behavior of trace amounts of protactinium in operations commonly used for dissolving ultra basic rocks. These studies are related to the determination of thorium in rocks at concentrations of the order of 10^{-3} parts per million. Po^{233} tracer has been prepared at the medical school cyclotron and experiments on recovering tracer from rock samples will be started as soon as our experiments on dissolving procedures have been completed.

Progress Report: The Use of Time Dependent Methods in Atomic and Molecular Quantum Mechanics

Principal Investigator: R. Yaris

NASA Grant NsG-581/26-08-006

The main research on time-dependent methods in the past year has resulted in the sharpening of the theoretical formulation of the time-dependent perturbation-variation method. In the original formulations [1,2] it was only possible to

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1. R. Yaris, J. Chem. Phys. 39, 2474 (1963); 40, 667 (1964)
2. M. Karplus and H. J. Kolker, J. Chem. Phys. 39, 1493 (1963)

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obtain a stationarity principle. However, recently we have shown[3] that, despite the fact that the time dependent Greens function itself does not

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3. R. Yaris, J. Chem. Phys. 43 3528 (1965)

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satisfy a minimum principle, we can (rigorously) use a minimum condition in its evaluation. This ability to use a minimum principle allows for a greater flexibility in the choice of variational functions and increases the power of the method.

Progress Report. Short-Lived Fission Products

Principal Investigator: Arthur C. Wahl

NASA Grant NsG-581/26-08-006

The automatic counting system requested last year has been purchased with funds provided by the USAEC. The NASA-University-Wide Research Funds provided to cover a portion of the cost of the system are being used to improve and expand this system and also to increase the usefulness of the dual parameter pulse-height analyzer recently acquired. An "Optikon Fast Digital Printer," a photographic device which allows prompt read-out of the analyzer, has been purchased, in part with NASA funds. Also, we plan to purchase either an automatic sample changer or a coupler to our IBM-526 card punch for direct read-out of the automatic counters to cards, which can be processed directly by the computer. The "Optikon" will be used in decay-scheme studies of short-lived fission products; the sample changer or coupler will be used in gathering decay data for determination of yields and genetic relationships of short-lived fission products.

Progress Report: Methods of Geophysical Exploration

Principal Investigator: Emil J. Mateker, Jr. and LeRoy Scharon

NASA Grant NsG-581/26-08-006

The major effort since the last progress report has been toward establishing satisfactory laboratory procedures for the measurement of conductivity and induced polarization, and the completion of preliminary measurements of these quantities on carbonate rocks. To date, only direct current fields have been used. The data from these experiments are currently being analyzed.

Although the analysis is incomplete, it would appear that the induced polarization method does not have sufficient resolving power to detect somewhat subtle changes in rock conduction properties. Samples were polarized in both dry and water saturated states. The decay properties vary considerably for these states for some carbonates and hardly at all for others. However, further analysis is necessary before a definitive conclusion can be reached.

One of the more interesting observations to date relates to the conductivity, or resistivity, experiments. It has been found that the resistivity of most of the carbonates tested increases as a function of saturation time in both distilled and tap water. This result is totally unexpected, for it has been thought that saturation would result in an equilibrium resistivity somewhat lower than that value measured after initial saturation. The cause of this observed increase in resistivity (decrease in conductivity) is not understood at the moment. It is interesting, however, to note that for some rocks the increase is linear to the equilibrium values whereas in others it is not. Some carbonates show little or no change as a function of time in saturation. Since the latter usually takes place with the lower resistivity carbonates, it is thought that they are nearly filled to capacity with interstitial fluids. Regardless of the nature of the rise to equilibrium, the time to equilibrium is nearly constant between nine and eleven days. This phenomenon is currently being pursued through some additional laboratory measurements.

Sample collection was completed on a dunite body, thought to be representative of mantle material, in North Carolina, and on a carbonate sequence in Indiana. Additional field sampling is not contemplated until initial tests on the samples available have been completed.

A laboratory procedure for wet chemical analysis of carbonate rocks has been established, and some preliminary analysis has been made. Complete analysis of a given sample takes about three weeks. Since our facilities permit simultaneous analysis of six or less samples, it will be some time before this phase of the program is complete.

Progress Report: Methods of Geophysical Exploration (Continued)

Principal Investigators: Emil J. Mateker, Jr. and LeRoy Scharon

Currently, we are in the process of extending our laboratory facilities to include dielectric and resistivity measurements as a function of frequency. To date, we had developed the capability for discrete frequencies to 100 kilocycles. The new equipment, which has been built and is currently being tested, will measure over a continuous range of frequencies to 10 megacycles. We cannot perform detailed experimental studies until a new, more precise cutting system is installed in our rock preparation laboratory. The latter should be completed in approximately four weeks. In the meantime, the new system is being minaturized with an eye toward future planetary exploration. This work is being carried on by Dr. Heinrich Soffel, a visiting post-doctoral research associate from the Institute of Applied Geophysics, University of Munich, Germany.

Our plans for the immediate future include: 1) more detailed analysis of the data already obtaineed in the laboratory; 2) experimental studies of conductivity and dielectric constants as a function of frequency to determine dispersion curves and the relative importance of electrolytic and displacement currents in the conductivity of carbonates and other rocks; 3) preliminary studies on the laboratory procedures for making studies of electrical properties of materials at higher temperatures and pressures; 4) design of experiments to test the possibility of dielectric measurements on the lunar surface during space flight missions.

Progress Report: Development of an Analog-to-Digital Conversion System

Principal Investigator: Emil J. Mateker, Jr.

NASA Grant NsG-581/26-08-006

The purpose of this project is to assemble an analog-to-digital conversion system on line to the PDP-5 computer in the Engineering Computer Laboratory. Through consultation with Dr. D. Wann of the Engineering Computer Laboratory an analysis sytem, which is composed of a Benson Lehner 17C Universal Reader with appropriate input-output equipment, has been designed. The equipment has been ordered and should be delivered sometime in January, 1966.

Computer programs to convert the output of the reader system to a form for further analysis on the IBM 7072 system are being developed for the PDP-5. Decisions have been made on those forms of analysis to be handled directly by the PDP-5.

Programs have been written for the IBM 7072 for certain forms of analysis of seismic data which will be converted to digital form by the system under development.

It is expected that the A - to - D system will be in operation early in the spring and that several researchers will be utilizing the system in current research before the end of the project.

Progress Report: Partitioning of Elements between Coexisting Phases in Granitic Batholiths

Principal Investigator: Kent C. Condie

NASA Grant NsG-581/26-08-006

During the summer months of 1965 the Precambrian batholithic complex in the northern Laramie Mountains in Wyoming was sampled in detail. Also, pegmatites from various parts of the Rocky Mountain region were sampled. Total rock samples from the batholithic complex have recently been analyzed for Fe, Mg, Ca, K, Mn, Ti, Si, Al, Ni, Zr, Rb, and Sr by X-ray fluorescence. Modal analyses are also presently underway.

Sample holders and other accessories for neutron activation analysis have been made and currently techniques are being developed for analysis of these samples for Sc, Co, Cu, Cr, Mn, and Na by this method. Arrangements are being made to use the new reactor facility at Columbia starting in the spring semester.

Mineral separations are now underway to study coexisting phases in pegmatites and in their surrounding host rocks. By the end of spring semester mineral separations should also be completed in some of the batholith samples from the Laramie Mountains. Pure mineral phases have been sent to various wet chemical laboratories and will serve as standards for X-ray fluorescence analysis of coexisting minerals.

During the next stage of the research, each major rock type within and adjacent to the batholithic complex will be sampled and chemically analyzed. Detailed field and structural geological studies will also be undertaken in the 2.5 - 2.7 billion-year-old Wyoming crust.

Plans are underway to study the paleomagnetic properties of the various rock types in ancient Wyoming crust with Dr. LeRoy Scharon. Rb-Sr age studies are also contemplated next year.

Progress Report: Engineering Computer Laboratory

Principal Investigator: Donald F. Wann

NASA GRANT NsG-581/26-08-006

During the past six months NASA funds have been used for the continued development of the Engineering Computer Laboratory. This laboratory was established to provide special purpose computing facilities not available in the University Computation Center, such as direct analog signal input channels, graphical display and communication (as with a light pen) and other hybrid computer features.

The basic holding of the facility consists of an Electronic Associates TR-48 analog computer and a Digital Equipment Corporation PDP-5 digital computer. The NASA support has allowed the acquisition of a sixteen channel 25KC rate multiplexed analog to digital converter, four 10 bit analog output channels, a hardware character generator for graphical display, a high speed photodiode light pen, magnetic tape storage equipment, and the necessary software developments to integrate these components into a useful system.

The addition of this equipment has greatly increased the value and flexibility of the computer services as evidenced by the increased interest of faculty and graduate students from virtually all divisions of the University. Departments currently using the services include Psychology, Earth Sciences, Biochemistry, Psychiatry, Physics, Mathematics, Biology, and all Departments of the School of Engineering.

Computer running time for the last half of 1965 is tabulated below:

Computer time (hours)

Month	Hours
July	83
August	123
September	144
October	166
November	176
December	113

To illustrate the type of research which is being assisted, five current projects are very briefly summarized here:

1. Enzyme Model Matching

   A complex model of a chemical enzyme has been postulated using a group of five parameters. This model is simulated on the digital computer, and using the graphical display capabilities, direct evaluation of parameter changes, via the typewriter, can be performed.

2. Helicopter Pilot Fatigue Prediction

   Fatigue of helicopter pilots may be evidenced by degradation of coordination as observed by timing changes in aircraft control surface actuation. A helicopter was equipped with an automatic recording device and then flown by various groups of pilots in prescribed maneuvers. Filtering, reduction, analysis and display of statistical coefficient related to the data is being handled in the laboratory.

3. Automatic Analysis of Geophysical Recordings

   The PDP-5 computer is being adapted to accept inputs from a Benson Lehner graphic reader for reduction of geophysical strip chart plots.

4. Correction of Radiation Measurements

   The accurate measurement of two dimensional radiation fields is impaired by the spatial dependence of radiation detectors, which produce image distortion. By using the detector image transfer function, an iterative technique has been developed for enhancement of the original field.

5. Automatic Contour and Line Following

   Work is currently in progress for the addition of an automatic black-white line follower to be used for direct entry of pictorial data into the digital computer. This will then be extended to allow isodensity tracking-useful for general photographic analysis.

Progress Report: Velocity and Temperature Profiles in Compressible Turbulent Free Jets

Principal Investigators: John Tomich and Eric Weger

NASA Grant NsG-581/26-08-006

Since April 1965 progress has been made on both the analytical and the experimental phases of the project.

1.) Experimental

All of the equipment is operational at the present time. In addition to the nozzle apparatus and instrumented impingement plate which were mentioned in the last report, total head probes, and stagnation temperature probes for defining conditions in the free jet have been secured. Associated with these is the probe positioning device which was fabricated in the Engineering School machine shop.

Several problems which were encountered during start-up of the equipment have been corrected. These included a burnout of some of the flexible tubing connecting the air heater to the nozzle, failure of some of the resistance elements in the heater, and failure of one of the temperature probes. Some difficulty was encountered due to movement of the nozzle when subjected to the high temperatures used in the experiments. This problem was solved by using surveying equipment to align the nozzle, the plate, and the probes optically after steady-state temperature conditions have been achieved.

Several successful experimental runs have been made to obtain date in the free jet and also conditions along the plate. The whole series of experiments has been planned and is presently underway.

2.) Analytical

Solutions for velocity and temperature in the free jet region have been obtained by means of computer solutions of the finite difference forms of the conservation equations. Semi-empirical expressions for the eddy transfer coefficients were used for these solutions. The resulting temperature and velocity profiles agree fairly well with existing (low temperature) data and the experimental results which have been obtained so far on the project. Discrepancies between experiment and calculation appear mainly in the jet region far removed from the axis. Refinements of the expressions for the transfer coefficients (incorporating radial dependencies) are being used in order to determine whether closer agreement can be obtained with these modifications. A paper which discusses the computational methods has been submitted for presentation at an AIAA convention in Los Angeles in June.

The analysis of the impingement region of the jet is underway. The results presently available permit prediction of the static pressure distribution on the plate and the stagnation point heat transfer rate, at least for the data presently available. However, more data are needed before absolute confidence can be placed on these results.

Progress Report: Application of State Variable Techniques to the Solution of Control Engineering Problems

Principal Investigator: John Zaborszky

NASA Grant NsG-581/26-06-008

The research was mainly centered around the applications of state variable techniques to the solution of control engineering problems under the following categories:

(1) The phase variable canonical form of state variable representation has the advantage of being amenable to analog computer solution. A transformation which reduces an arbitrary state representation to the phase variable canonical form was developed. (Published as "The Transformation to (Phase Variable) Canonical Form", M. R. Chidambara IEEE Transactions on Automatic Control, July 1965.)

(2) A relation between the state variables and the outputs and their derivatives was established. (Published as "Relation between the state variables and the outputs and their derivatives", M. R. Chidambara, CONTROL, November 1965, pg. 607.)

(3) Multivariable systems with multiple eigenvalues, had not yet been studied satisfactorily from the state variable point of view. A method of obtaining the state variable representative for this case and the corresponding straight forward solution was developed. (Published as "State variables for multivariable Systems with multiple Eigenvalues", M. R. Chidambara, IEEE Transactions on Automatic Control, January 1966. (To be published).)

(4) In digital control systems where the input is piecewise continuous, the control law to satisfy certain performance indices requires the input to the controlled element to be a linear combination of the state variables which in general are not separately available for measurement. A procedure was developed to tackle this problem to determine the state variables from available measurements. (Published as "State variable determination for digital control", M. R. Chidambara and C. H. Wells. IEEE Transactions on Automatic Control, April 1966 (To be published).)

(5) In general, the state variables are not available for direct measurement. A method was developed to determine the state variables for known plants. This method which utilizes integrals of inputs and outputs has the inherent noise suppressing characteristics. (Published as "A Method of Determination of State Variables for known Plants", M. R. Chidambara, and John Zaborszky, IEEE Transactions on Circuit Theory. (Publication pending).)

Common Facilities

NASA Grant NsG-581/26-06-008

CHEMISTRY

Grant funds were used for the purchase of large items of equipment which are necessary to enable the research programs to proceed with a sufficient degree of sophistication.

The following new instruments already are in operation or they will be delivered shortly:

High resolution grating spectrograph
Microphotometer
X-ray diffraction apparatus
Varian A-60A NMR spectrometer
Vapor phase chromatographic apparatus, preparative scale
Flash photolysis unit and giant pulse ruby laser
Brice-Phoenix light scattering photometer.

In addition to the above, a great deal of modern equipment for experiments in nuclear chemistry is now in operation.

EARTH SCIENCES

$680.00 from the NASA Multi-disciplinary Research Grant was combined with funds available from other sources to a total of $2776.00 for purchase for the department of a WL POL Zeiss polarizing reflected light microscope.

This microscope will be used in the department for many students but has been and at the moment is being used to study domain structure and distribution of magnetic opaque minerals in igneous rocks.

PHYSICS

For the success of the various programs in space-related physics it is essential that there be funds for certain vitally necessary common facilities. The new Compton Laboratory has presented the opportunity for vigorous development of the programs. However the additional research space cannot be used effectively unless common facilities are provided.

Common facilities acquired to date under the present grant include a precision milling machine, a hydraulic fork lift, a die machine and a multi-channel data processor.